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Performance Analysis of WiMAX Networks with Relay Station

Khan Mubeen Ahmed[1], Kansal Sarita[2] and Tiwari Vibha[3]
Medicaps Institute of Technology, Department of Computer Science and Engineering
makkhan0786@gmail.com[1], sarita_1411@yahoo.com[2] and getvibha@gmail.com[3]

Abstract - **IEEE 802.16 is a Broadband Wireless Access (BWA) network and thus it is considered to be an alternative solution to wired broadband technologies. Relay station plays a promising role of extending the range of Base station for long distances in WiMAX networks. Relay station is suitable to areas with limited infrastructure such as rural, hilly and lakes, where it is difficult to install many Base stations with each having wired connections and it is also suitable to those phases where obstacles made the coverage limited. The Relay station is placed in the network connectivity from Base stations and extends the coverage of a single Base station. In this paper the performance analysis of WiMAX technology including Relay station has been done. This paper also focuses on increasing number of nodes and distance from base station to the performance of WiMAX networks.**

***Index Terms*: 802.16, Light WiMAX Simulator (LWX), Bandwidth Allocation Algorithm (BWA)**

I. Introduction

Broadband Wireless Access (BWA) is a solution for rapid requirement of internet connection for data, voice and video services. BWA is a fast and easy alternative of cable networks and Digital Subscriber Line (DSL) technologies [1]. The IEEE working group has designed a new standard based on BWA systems for last mile wireless access named IEEE 802.16[2]. The IEEE 802.16 architecture is designed to achieve goals like easy deployment, high data rate, large area and large frequency spectrum. The IEEE 802.16 emerge as a dominant technology for cost competitive ubiquitous broadband wireless access, supporting fixed, nomadic, portable and fully mobile operations offering integrated voice, video and data services. The point to multipoint (PMP) architecture of IEEE 802.16 can be deployed in easy and cost effective manner in crowded geographical areas (metro cities) and rural areas where no wired infrastructure is available. Relay stations add an additive advantage for data to be transferred for different services. The point to multipoint (PMP) architecture of IEEE 802.16 consists of one Base Station (BS) and many Subscriber Stations (SSs) including Relay stations. Clients are connected to SS for data transfer or any SS can itself be a client. All SSs have to be synchronized with BS. SSs are also allowed to send data via a Relay station where coverage area is not supported by Base stations. The BS communicated to all SS in the beginning of each frame via Uplink Map (UL MAP) [3].

Many researchers have presented mechanisms for transporting data with Light WiMAX. Most of these works focus on IEEE 802.16 bandwidth allocation algorithms. The contribution of LWX is in the area mainly focused on QoS, OFDMA, and multi hop relay. LWX also provided a mechanism for dynamic binding for user to plug and play different algorithms without modifying and recompiling those algorithms which analyze bandwidth allocation. Relay station is one of the important research area related to this field which is analyzed here.

II. Relay Station

IEEE 802.16j is an enhancement to previous 802.16 standards to provide support for relays, thus providing for increased capacity and/or coverage, depending on the scenario[4][5]. The standard does not permit changes to SSs, hence the changes introduced by the standard focus on communications between (enhanced) BS and the new RSs. One issue which arises in this context is how to approach network planning a multi-hop radio access network gives rise to new problems which have not been addressed in previous radio planning approaches. Here, it is proposed how RS gives benefit to a set of BSs and SSs. In this work, the benefit of using RS in a network of BS and SS has been proposed. Multihop relay (MR) is may be used to provide additional coverage or performance advantage in an access network [4].

In MR networks, the BS may be replaced by a multihop relay BS (MR-BS) and one or more relay stations (RS). Traffic and signaling between the SS and MR-BS are relayed by the RS thereby extending the coverage and performance of the system in areas where RSs are deployed. Each RS works under the supervision of an MR BS. In a more than two hop system, traffic and signaling between an access RS and MR-BS may also be relayed through intermediate RSs. The RS may be fixed in location (i.e., attached to a building) or, in the case of an access RS, it may be mobile. The SS may also communicate directly with the MR-BS. The various MR features defined throughout this standard permit a multihop relay system to be configured in several modes. New functionality has been specified on the relay link to support the MR features. Two different modes centralized and distributed scheduling) are specified for controlling the allocation of bandwidths for an SS or an RS. In centralized scheduling mode, the bandwidth allocation for an RS's subordinate stations is determined at the MR BS; conversely in distributed scheduling mode, the bandwidth allocation of an RS's subordinate stations is determined by the RS in cooperation with the MR-BS. Two different types of RS are defined, namely transparent and

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non-transparent [4]. A non-transparent RS can operate in both centralized and distributed scheduling mode, while a transparent RS can only operate in centralized scheduling mode. A transparent RS communicates with the superordinate stations using the same carrier frequency. A non-transparent RS may communicate with the super ordinate station and subordinate stations using the same or different carrier frequencies.

Relay based networks has small form factor, low cost relays associated with Base stations[6][7]. Three main benefits provided from relay based architecture over single hop architecture are throughput enhancement, coverage increase and deployment cost. It is expected to increase system capacity by deploying RSs in a manner that enables more aggressive spatial reuse. The relay technology is expected to improve the coverage reliability in geographic areas that are severely shadowed from the BS and/or to extend the range of a BS. Relay based systems have the potential to deliver cost gains over traditional single hop wireless access systems. Using RSs, an operator could deploy a network with wide coverage at a lower cost than using only (more) expensive BSs to provide good coverage and system capacity. Relaying techniques include the conventional techniques of time domain, frequency domain, hybrid time frequency domain and cooperative time relaying domain techniques [8][9].

III. Network Setup And Simulation Study

The network setup is used to analyze the performance of Light WiMAX with Relay Station. Two different scenarios are considered each including a Base station Subscriber stations and Relay stations.

A. *WiMAX With_Relay Station (Topology)*

Topology as shown in fig.1 is used for the performance analysis of Relay station in Light WiMAX.

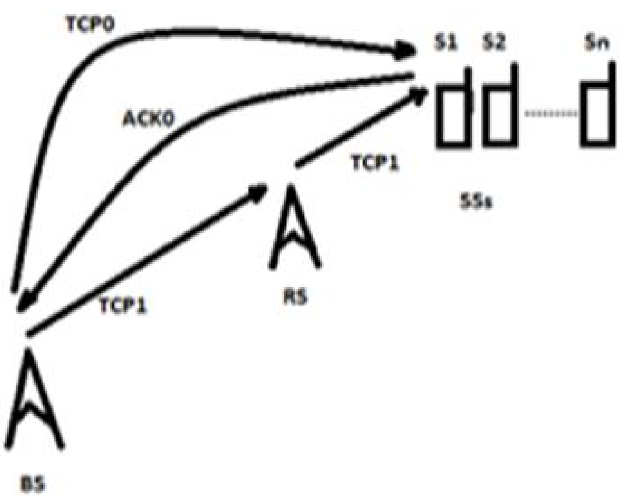

Fig. 1 Case_with_RS

The simulation topology above contains one BS, one RS and many SSs. The connections from BS to SS are taken downlink and various cases are taken to analyze the performance. The downlink transmission is relayed by BS to SSs via RS as well as BS to SSs without RS. TCP connections are created for uplink packet transmission with Ack. There are two downlink TCP connections from BS to SSs (one TCP connection via RS and another TCP connection without RS).

B. *WiMAX Without_Relay Station (Topology)*

The simulation topology as shown in fig. 2 below contains one BS and many SSs. The connections from BS to SSs are downlink connections from BS to SSs. TCP connections are created for downlink packet transmission with Ack. Following topology is used for performance analysis of Light WiMAX without relay station. The downlink transmission is relayed by BS to SSs. TCP connections are created for uplink and downlink packet transmission with Ack. There is a downlink TCP connection from BS to SSs.

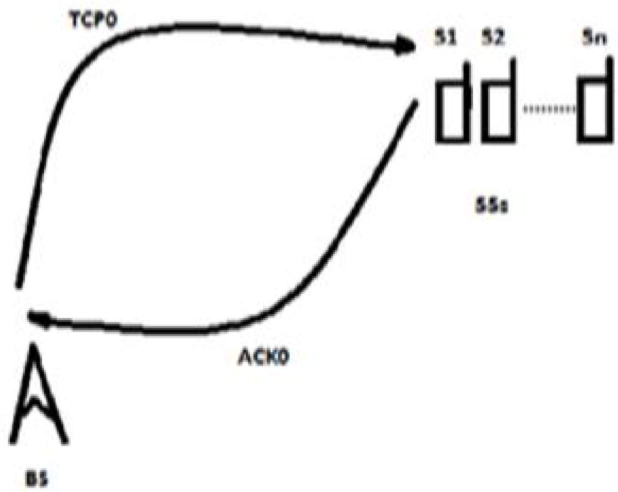

Fig. 2 Case_without_RS

III. Simulation Parameters

The performance of Relay stations is analyzed in WiMAX scenarios by considering following simulation parameters given in table I:

Table I. Parameters Used for Simulation

Parameters	Value
Routing Protocol	AODV
Transmission Protocol	TCP
Bandwidth Allocation Algorithm	Round Robin for Relay
Simulation Time	300 Sec
Number of Nodes	5,15,25,35,……..……..95

IV. Performance Metrics

The three performance metrics are considered to evaluate the performance:

- *Throughput* that measures the amount of raw bytes sent by a source.
- *Goodput* that measures bytes that are successfully received.
- Number of dropped packets

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V. Results

It is observed from the graph shown below in fig. 3 that the value of throughput is obtained maximum shown when distances of nodes are nearer to base station because higher order modulation techniques is used with OFDM. Multiple bits are carried in a single OFDM symbol. A wireless channel suffers from delay spread due to the existence of multiple propagation paths (especially in NLOS conditions). When the data symbol is longer, the delay spread is a small and insignificant fraction of the symbol length, so the effect due to delay spread is minimized.

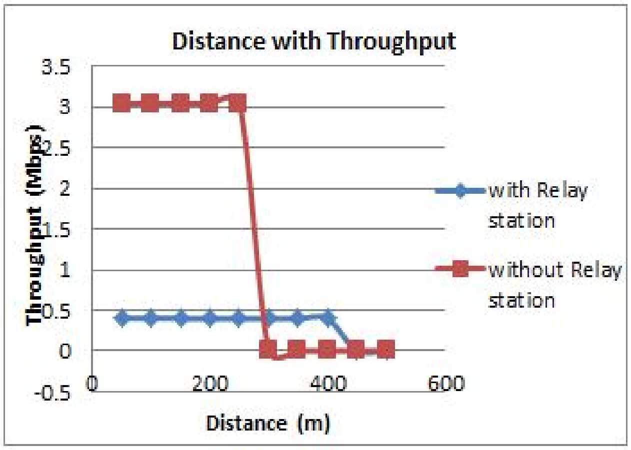

Fig. 3 Coverage of Relay station with distance and Throughput

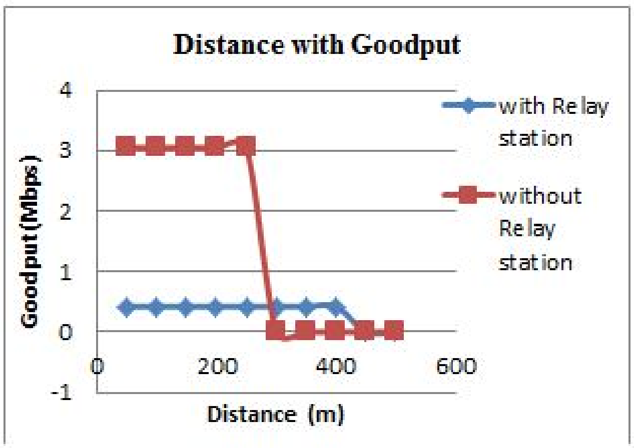

Fig. 4 Coverage of Relay station with distance and Goodput

It is observed from the graph shown in fig 4 that the value of Goodput is obtained maximum when distance of nodes are nearer to base station for Downlink connection. This is due to the fact that as number of packets per second transferred also increases, data transmission capacity of channel also increases and hence is obtained highest near to base stations. As distance of nodes from base station increases, it is observed that after a limited distance, the coverage of base station ends and the goodput becomes zero. If we add a Relay station then the coverage area of base station is enlarged to more distance and data could be transferred to more distances effectively. Also It is observed from graph shown that as the distance increases dropped packets also increases. In case of with Relay station, it is observed that number of dropped packets with relay station are more than without relay station and this is due to the fact that when packets are send directly then there is less possibility of packets to be lost since the signal is transmitting with maximum power from base station. As the traffic load increases then calls are not serviced properly and are dropped after long waiting time [10].

It is observed that from fig. 5 below that Dropped packets are also increased since high modulation cannot be maintained over the entire length of the link or in a Non Line of sight environment. For such cases the error rates rises and the adaptive modulation feature drops the modulation to lower density modulation.

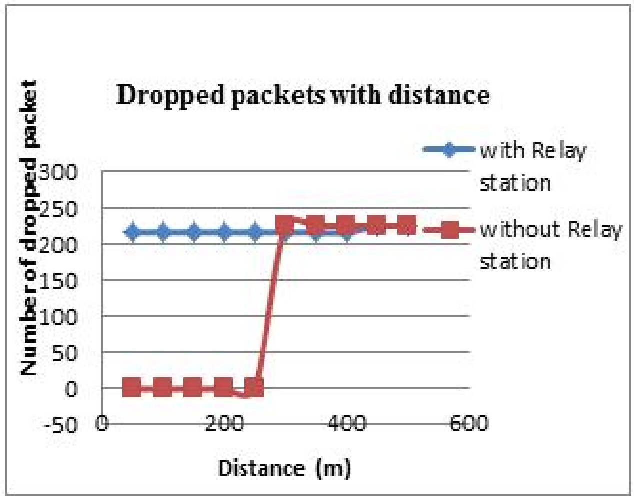

Fig. 5 Coverage of Relay station with distance and Dropped packets

WiMAX being able to provide up to 38 Mbps over 25 Km for 10 MHz bandwidth would not be factually correct for all distances. The data rates changes through the entire coverage area and depends on whether the reception is LOS or NLOS. In case of NLOS reception the data retes drop significantly because of change of modulation [11].

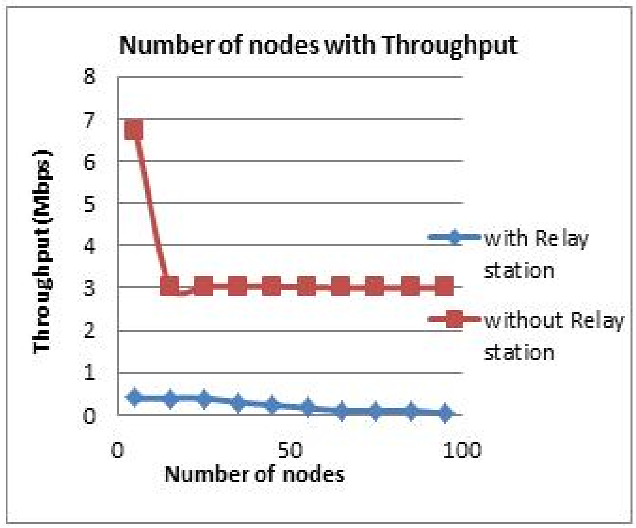

Fig. 6 Coverage of Relay station with Number of nodes and Throughput

It is observed from the graph shown in fig 6 that throughput per user is decreased when number of subscriber sta

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tions increases. This implies that for full utilization of relay station, the use of wider channel is necessary. If this condition is satisfied, the system capacity may be increased, e.g. for 15 active users, the bit rate per user is improved from 0.4 Mbps to 6.73 Mbps. It is observed that nominal bit rate is obtained 0.03 Mbps up to 95 users against 3 Mbps up to 95 users without Relay station before congestion occurs.

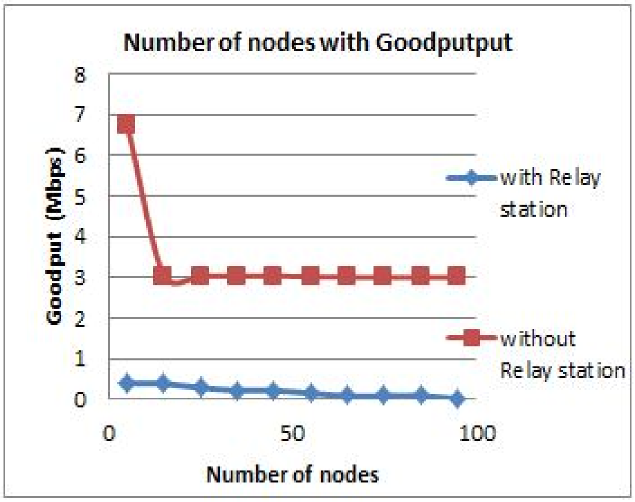

Fig. 7 Coverage of Relay station with Number of nodes and Goodput

It is observed from the graph shown in fig 7 that the Goodput per user is decreased when number of subscriber stations increases. fig 7 indicates that for channel size 3 MHz the performance with or without Relay station is identical. This implies that for full utilization of relay station, the use of wider channel is necessary. If this condition is satisfied, the system capacity may be increased, e.g. for 15 active users, the bit rate per user is improved from 0.4 Mbps to 6.73 Mbps. It is observed that nominal bit rate per goodput user is 0.03 Mbps up to 95 users without Relay station before congestion occurs.

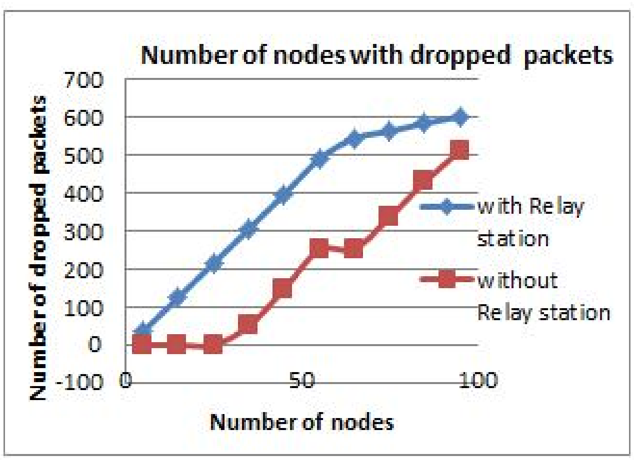

Fig. 8 Coverage of Relay station with Number of nodes and dropped packets

It is observed from the graph shown in fig 8 that as number of nodes increases dropped packets also increases. In case of with Relay station it is observed that number of dropped packets are more than without relay station and this is due to the fact that when packets are send directly then there is less possibility for packets to be lost since the signal is transmitting with maximum power from base station. As the traffic load increases then calls are not serviced properly and are dropped after long waiting time [8]. Dropped packets are also observed increased since high modulation cannot be maintained over the entire length of the link or in a Non Line of sight environment. For such cases the error rates will rise and the adaptive modulation features will drops the modulation to lower density modulation .This means that the data rate will drop.

VI. Conclusion

In this paper the performance of WiMAX system is analyzed when relay stations are employed and when relay station is not employed. The simulation results show that adding relay station to base stations increases the coverage of base station and it is observed that after 250 m it is 100 percent higher than without relay station. Also adding Relay station could add more number of nodes to the base stations for long distances. When number of nodes increases it is observed that throughput is obtained higher than with relay station. As number of nodes increases value of throughput is observed higher with 65 nodes with relay station. Similarly for goodput also, initially the value obtained higher than with relay station up to distance up to 200 meters. But as the distance increases after 200 meters the value of goodput with relay station is obtained higher than without relay station. When distance increases it is observed that dropped packets are obtained higher than with relay station. Similarly for number of nodes also initially dropped packets is less but as nodes increases value of dropped packets also increase for both cases, also dropped packets increases with relay stations.

VII. Future Work

Further studies can be carried out about the performance of relay station with various bandwidth allocation techniques with different Quality of Services parameters. WiMAX network by increasing the number of relay stations could give performance of many relay stations. This whole analysis could also be done with UDP protocols and with IPV-6 version.

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